Learning Centre — Science

Chemistry 0871

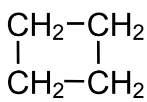
by Darren Rigby

Naming Organic Compounds 2

Naming Organic Compounds 1 described how to name straight-chain hydrocarbons and their derivatives. (If you aren't familiar with the systematic nomenclature for those compounds, do that worksheet first, and do this one later.) This worksheet will describe how to name simple cyclic hydrocarbons, aromatic compounds, and organic compounds with common functional groups.

CYCLOALKANES AND CYCLOALKENES

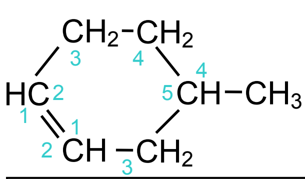
To name a cycloalkane or cycloalkene, add the prefix **cyclo-** to the parent name of the straight-chain hydrocarbon it resembles.



cyclobutane

This cyclic hydrocarbon is a loop with 4 carbons in it and no multiple bonds. The straight-chain version would be butane, so this is **cyclobutane**.

When there are other substituents on the outside of the ring, we number the carbons around the ring so that multiple bonds are at the lowest numbers, or if there aren't multiple bonds, the total of the numbers is lowest.

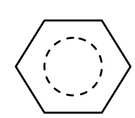


4-methyl-1-cyclohexene

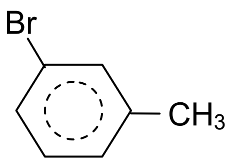
There is a ring of 6 carbons, including a double bond. That makes this a cyclohexene. The methyl group might have been added to any of the carbons, so we must number its position. The carbons at the double bond must be #1 and #2 in some order. (Multiple bonds take precedence in numbering, just as in straight-chain hydrocarbons.) Going clockwise puts the methyl on #5; going counterclockwise puts it on #4. This is **4-methyl-1-cyclohexene.**

AROMATIC HYDROCARBONS

The basic aromatic hydrocarbon is called **benzene**, C_6H_6. It resembles a cyclohexene (or, really, 1,3,5-cyclohexatriene — try drawing that structure!), but rather than having alternating single and double bonds, the benzene ring has three delocalized bonds around the ring. Benzene has a symbol in diagrams, which is shown on the right. Because benzene has a completely symmetrical structure, it only requires numbering when more than one group is added to it. When a benzene ring appears in a more complicated compound as a group, it's called a **phenyl** group.



benzene



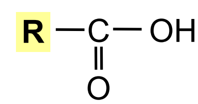
1-bromo-3-methylbenzene

The benzene ring here has a bromine and a methyl group added to it, so we must number them, but no matter which way we number, we get a 1 and a 3. There's no way to decide. The convention is to put the numbers in order as they appear in the name, so this is **1-bromo-3-methylbenzene**.

FUNCTIONAL GROUPS

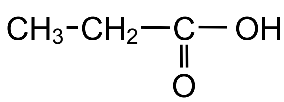
There are other chemical groups that often appear in organic compounds, and these often contain oxygen or nitrogen. They greatly alter the chemical behaviour of a compound. These **functional groups** override the presence of halogens or alkyl groups when deciding on a name for a compound. They're presented in decreasing precedence here.

Carboxylic acids



carboxyl group

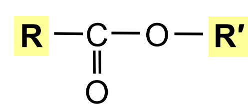
Carboxylic acids have had one of the carbons at the end of the chain replaced with the carboxyl group shown at the right. The **R** means that any organic fragment might appear there. The "R" stands for "radical". To create the names of compounds like this, take away the -e at the end of the straight-chain hydrocarbon and replace it with **-oic acid**.



propan**oic acid**

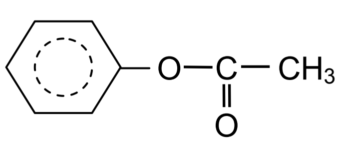
This compound has the -COOH group at the end, so this is a carboxylic acid. The C in the carboxyl group is part of a chain of 3 carbons, which resembles propane. Replace the "-e" with "-oic acid", and you get the systemic name: **propanoic acid**.

Esters



ester group

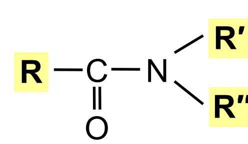
Esters can be thought of as "salts" of carboxylic acids. It's the H in the –COOH group that makes the molecule behave as an acid. When it's removed, the resulting compound is an ester. In the same way that we can take nitric acid (HNO_3), remove the H and be left with a nitrate (NO_3^-), we can take propanoic acid from the previous example ($CH_3CH_2COO\textit{H}$) and get a propanoate ($CH_3CH_2COO^-$) by removing that H. The ending **-oate** tells you it's an ester. The rest of the molecule is written as a group, such as in ethyl, not ethane.



phenyl ethan**oate**

This is an ester, but is this a benzoate, or an ethanoate? To decide, we must look at the orientation of the –COO– group in the middle. The benzene ring has replaced the H in the structure of the acid, so the acid this came from is ethanoic acid. This is an ethanoate with a phenyl group (from the benzene ring), or **phenyl ethanoate**.

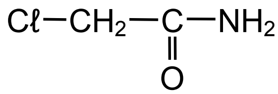
Amides



amide group

Amides are also derivatives of carboxylic acids, but the –OH has been replaced with a nitrogen from an amine (which is later in this worksheet).

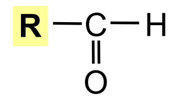
For your courses here, we'll stick to naming compounds where both R′ and R″ are just hydrogen atoms. In that case, we replace the -e from the end of the hydrocarbon at R with **-amide**.



2-chloroethanamide

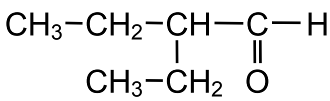
The amide group is in a chain of 2 carbons, like ethane. This is an ethanamide. There's a chlorine on the other carbon. We number it, but since the functional group takes precedence, we call the carbon in the amide #1, so this is **2-chloroethanamide**.

Aldehydes



aldehyde group

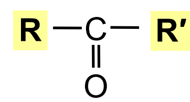
Aldehydes also contain a double-bonded oxygen, and as in a carboxylic acid, the aldehyde group can only appear at the end of a molecule. Rather than an –OH, there's just a hydrogen atom. To make the name of an aldehyde, we replace -e with **-al** to the end of a hydrocarbon.



2-ethylbutan**al**

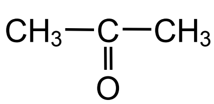
We have an aldehyde group attached to a 4-carbon chain. There *is* a 5-carbon chain, but since it does not contain the functional group, we don't use it for the name. This is, then, a butanal. We use the functional group as carbon #1, which puts the ethyl group at #2. This is **2-ethylbutanal**.

Ketones



carbonyl group

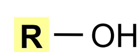
Ketones cover all other compounds that have a double-bonded oxygen in them. Since the oxygen does not have to appear at the end of a chain, we must number the position of the oxygen. This numbering takes precedence over multiple bonds among carbons, halogens and "subchains" (but does not take precedence over anything earlier in this list). To form the name of a ketone, replace the -e from the name of the chain with **-one**, pronounced as in "phone". If there is more than one carbonyl group, prefixes (di-, tri-, tetra-,…) are added before -one.



2-propan**one**

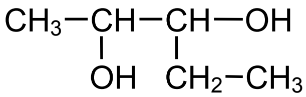
This compound is commonly known as *acetone*, and it's found in nail polish remover. For the systemic name, we notice that this is a ketone with a 3-carbon chain. We should number the position of the functional group. Either way, this becomes **2-propanone**. (You might argue that the number isn't necessary. Do you see why?)

Alcohols



hydroxyl group

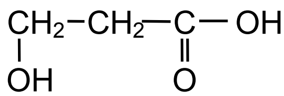
Alcohols have an –OH group in them. As in ketones, the hydroxyl group shown at right can appear on any carbon atom, and so must be numbered. The –OH decides which way to number (unless something earlier in this list also appears). The name of an alcohol has **-ol** at the end, formed the same way as the other compounds in this list. A prefix is added before the -ol if there are multiple hydroxyl groups.



2,3-pentanedi**ol**

There are two hydroxyl groups in this molecule, and nothing higher on the list, so this is an alcohol. The OH groups are on a 5-carbon chain. Going from the left gives the lowest numbers. We start with pentane, and if there were just one –OH, we'd call this "pentanol", but with two, we include "-di-" to make **2,3-pentanediol**. (We keep the -e to keep the long A sound in -ane.)

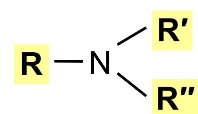
[*Optional*] We've described the order of this list a few times, but we haven't had more than one functional group in a molecule yet. The later groups get added as prefixes just like *chromo-* or *methyl-* when there's a conflict. You can see this in the next example.



3-hydroxypropanoic acid

Here, we see two different functional groups: a –COOH to make a carboxylic acid, and another –OH. (The –OH in the acid group doesn't count because it's part of a larger group.) Carboxylic acids have precedence over alcohols, so this molecule behaves as an acid, not as an alcohol. The ending of the name is "-oic acid", we use the carbon chain that starts at the –COOH, and we number the carbons from that end of the molecule. The chain is 3 carbons long (derivative of propane), and the –OH is at carbon #3. As a prefix, the functional group for an alcohol is called *hydroxy-*, so this is **3-hydroxypropanoic acid**. (Similarly, the ketone group is called *oxo-* when something with higher preference is in the molecule.)

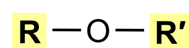
Amines



amine group

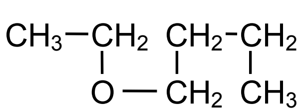
Amines are organic compounds which contain a nitrogen atom. As with amides, the naming conventions get complicated, so we'll only look at primary amines, where R′ and R″ are replaced by hydrogen atoms. In this type of molecule, the amine is often written NH_2. If it is the highest priority functional group, it is represented by the suffix **-amine**, and numbering starts from the end nearest the nitrogen. If it's not the highest functional group, it is represented by the prefix *amino-*.

Ethers



oxy group

Ethers are the last kind of organic compound we'll be covering. They contain an oxygen bonded to two carbon atoms. It's important to distinguish ethers and esters. Both have –C–O–C– sequences in them, but esters have an oxygen double bonded to one of those two carbons; ethers *never* do. The simplest kind of ether has the ends of two carbon chains bonded to the oxygen. The proper way to name these compounds is to put the shorter chain first (with -ane removed if it's an alkane, and -e removed otherwise), then **-oxy-**, then the longer chain, as in this example:



eth**oxy**butane

The carbon chain has been interrupted by an oxygen atom, so this is an ether. The two chains that result are a 2-carbon chain (ethane) and a 4-carbon chain (butane). The shorter chain is an alkane, so it gets shortened to eth-. This molecule is **ethoxybutane**. (If the chain on the left had had a double bond, it would have been ethenoxybutane.)

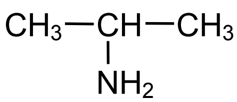
The table at the right summarizes all the information you have about the functional groups in this worksheet in order of priority. Naming organic compounds can get complicated, but it comes down to simple steps: Find the highest priority **functional group**, identify the **carbon chain** and number it, identify **side chains** and their positions, and put all the pieces of the name in order.

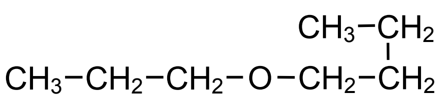
COMPOUND	STRUCTURE	NAME	PREFIX
carboxylic acid	$R-\overset{\|\|}{C}(O)-OH$	*R*-oic acid	
ester	$R-C(=O)-O-R'$	*R*-oate	
amide	$R-C(=O)-N(R')(R'')$	*R*-amide	
aldehyde	$R-C(=O)-H$	*R*-al	methanoyl-
ketone	$R-C(=O)-R'$	*R*-one	oxo-
alcohol	$R-OH$	*R*-ol	hydroxy-
amine	$R-N(R')(R'')$	*R*-amine	amino-
ether	$R-O-R'$	*R*-oxy-*R'*	oxy-

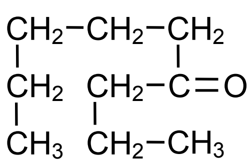
EXERCISES

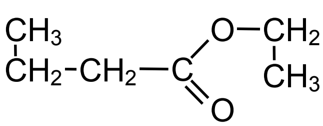
A. Name these organic compounds:

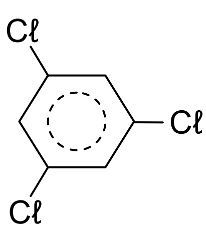
1) CH_3-OH

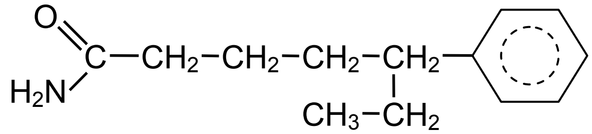
2) 

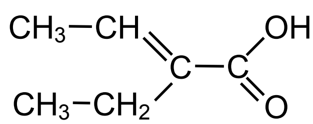
3) 

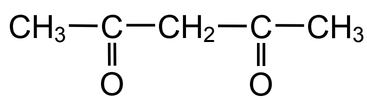
4) 

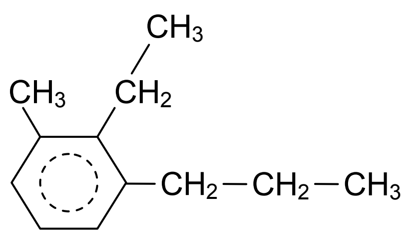
5) 

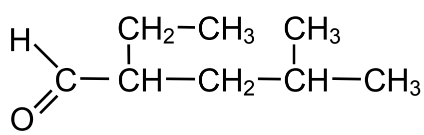
6) 

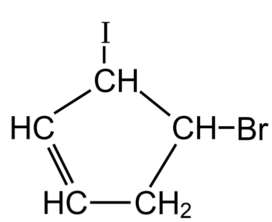
8) 

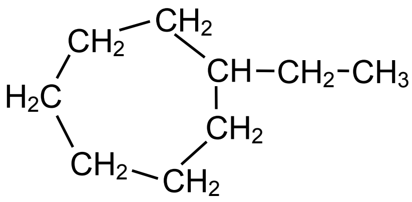
9) 

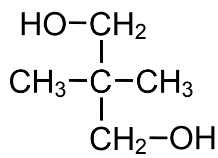
10) 

11) 

12) 

13) 

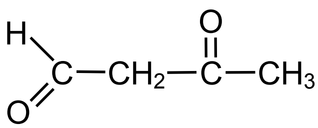
7) 

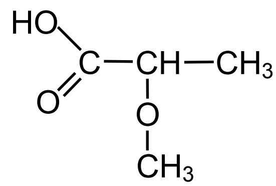
14) 

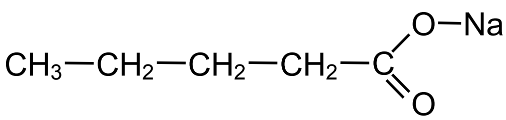
B. Draw the structural diagrams for these compounds:

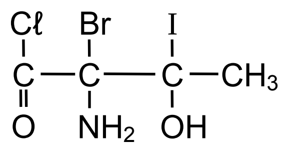
1) methoxyoctane
2) propanamide
3) 2-propynal
4) propylcyclobutane
5) 2,5-dimethyl-3-hexanone
6) 1,3-butanediol
7) phenyl butanoate
8) 2-ethyl-1-butanamine
9) 2-bromo-1,4-dimethylbenzene
10) 5-propylheptanoic acid

C. **Optional.** Name these organic compounds:

1) 

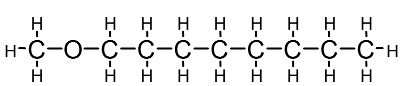
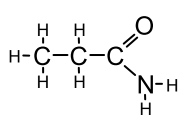
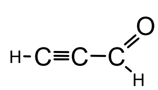
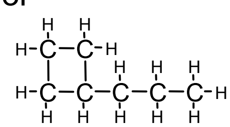
3) 

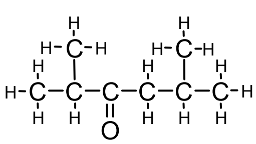
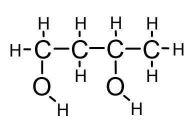
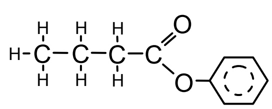
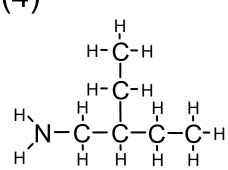
2) 

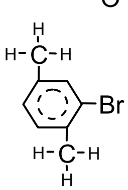
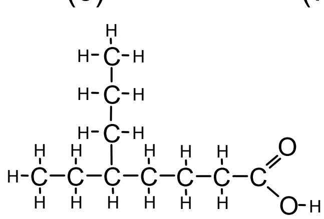
4) 

SOLUTIONS

A. (1) methanol (2) 2-propanamine (3) propoxybutane (4) 4-nonanone (5) ethyl butanoate (6) 1,3,5-trichlorobenzene (7) ethylcycloheptane (8) 5-phenylheptanamide (9) 2-ethylbutenoic acid (10) 2,4-pentanedione (11) 2-ethyl-1-methyl-3-propylbenzene (12) 2-ethyl-4-methylpentanal (13) 4-bromo-3-iodocyclopentene (14) 2,2-dimethyl-1,3-propanediol

B. (1)  (2)  (3)  (4) 

(5)  (6)  (7)  (8) 

(9)  (10) 

C. (1) 3-oxobutanal (2) sodium pentanoate (3) 2-methoxypropanoic acid (4) 2-amino-2-bromo-1-chloro-3-hydroxy-3-iodo-1-butanone